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Synchronous FM

A New Approach

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Abstract

Advances in DSP driven Digital FM Exciters have provided new opportunities for the implementation of synchronous FM broadcasting using multiple transmitters operating on a single frequency. With the limited availability of new FM frequencies in many developed markets, the need to reduce pressure on FM spectrum allocations by using a single frequency for all transmitters for a station, as well as the movement to reduce individual transmitter output power for public health reasons, the introduction of this technology is timely and of significant interest for FM broadcasters world-wide.

What is an FM Booster?

The objective is to broadcast a common audio program source through multiple transmitters at diverse locations, all identical in modulation and locked to a single frequency. The applications of this approach include:

- The filling of shadow areas or “dead spots” within an FM station’s existing licensed contour.
- Increasing coverage of an FM station to serve a larger region than would be possible with a single transmitter, without requiring the listener to change frequencies on his receiver as he travels from one area to another. In this way, an entire state, province or even country can be covered by a single broadcaster, all transmitted on a single recognized frequency.
- A network of low power synchronized transmitters can be used to provide unbroken service along the entire length of a major highway.

However, the operation of an FM booster introduces a significant complication wherever the main and booster signals can both be detected by the same receiver. There is no problem if the difference in signal strengths is greater than 15-20 dB, because the FM receiver’s “capture effect” causes the receiver to completely ignore the weaker signal. However, when the signals are relatively equal in strength, the receiver cannot separate them and audible distortion is heard. The effect is similar to multipath distortion, where a receiver detects both direct path and reflected signals and generates an audible noise dependent upon the phase difference between the signals. In the case of a booster, however, the noise and distortion can be much more severe due to differences between the modulation envelopes of the two signals.

Past Experiences with FM Boosters

FM broadcasters who implemented synchronous booster systems in the past found that the areas in which the signals from the primary and booster transmitters overlapped, called "mush zones", often suffered from unacceptably severe distortion. Further, in addition to these primary overlap areas, pockets of interference were also being generated in random locations throughout the coverage area, wherever propagation conditions reduced the carrier level difference between the two signals. Until recently, the only truly successful booster stations were installed in locations where the main and booster signals were effectively isolated due to severe terrain shielding.

It is important to recognize that in the best of cases simultaneous FM broadcasting deliberately introduces multipath distortion into the system. The primary consideration in engineering a synchronous FM system is to keep this distortion to a minimum by proper RF design of the system. Regardless of the amount of effort invested in the system, installation or maintenance, this multipath is never completely eliminated.

Analog synchronous FM systems have been in use for a number of years. Broadcast Electronics introduced booster technology in 1988 that synchronized the booster exciter to a reference frequency generated in the main station's exciter and transmitted to the booster via STL. This technology allowed synchronization of the carrier frequencies but it did not equalize all aspects of the modulation envelope. It was found that unacceptable noise and distortion was generated even when the carrier frequencies were synchronized.

Shortly thereafter, an improved method was introduced by TFT. Their "Reciter" technology up-converts the signal from the main station's exciter to an STL frequency for transmission to the booster site. Once at the booster site, the RF envelope is down-converted back to the FM station's frequency. This was an improvement because there was only one stage of FM modulation in the chains feeding both transmitters. But problems still existed because the signals were not identical due to non-linearities in the individual RF converter stages and analog STL path.

Further studies of synchronous boosters found that:

- If the RF carriers are not frequency synchronized, terrible distortion and noise results.
- If the audio levels are not exactly the same, the noise floor increases dramatically in the form of a "white noise" which varies with the level of the audio.
- If the stereo pilots are not synchronized, the pilot detector in the receiver will switch back and forth and this will be audible in the stereo signal.
- If the audio phase is not synchronized, noise and distortion is created.
- If everything – audio, pilot & carrier - are all synchronized, the signal will sound like a normal multipath condition.

What was needed was a way to exactly synchronize and lock both the carrier and pilot frequencies, and to precisely match the audio level. Additionally, a method was needed to delay the audio at one of the transmitters so that the two audio signals would arrive at the interference zone precisely in phase.

While the requirements were understood in principle, they were difficult to achieve in a practical analog system. The solution was not found until recently with the introduction of uncompressed digital audio STLs and digital FM exciters.

Booster Problems Solved with Digital Exciter Technology

In 2002, Broadcast Electronics introduced the FXi Series exciters; the first digital FM exciter in the industry to employ Direct to Channel (DTC) modulation based on a digital signal processing platform. Among its many other benefits, the FXi exciters allowed the possibility of a totally digital approach to synchronous FM that provides significantly reduced distortion artifacts in mush zones. This exciter now makes it possible to synchronize the pilot and the carrier, as well as the audio amplitude and frequency of two or more overlapped transmissions, thus reducing the interference issues associated with synchronous FM.

There are other digital approaches on the market, but these do not synchronize all the possible characteristics of the modulation waveform. The FXi Digital Exciter is unique in that it is the first to synchronize the carrier frequency, pilot frequency, audio amplitude and modulation precisely, therefore improving signal to noise performance in the signal overlap areas. The FXi exciter also accepts an external digital carrier reference, enabling two FXi exciters to be synchronized to a common carrier frequency referenced to a GPS satellite receiver.

The phase of the pilot is synchronized in the system by the Pilot Sync Kit – which compares the leading edge of the 19kHz pilot with a 1PPS signal derived from GPS and delays the internal pilot in the FXi exciter until sync is achieved.

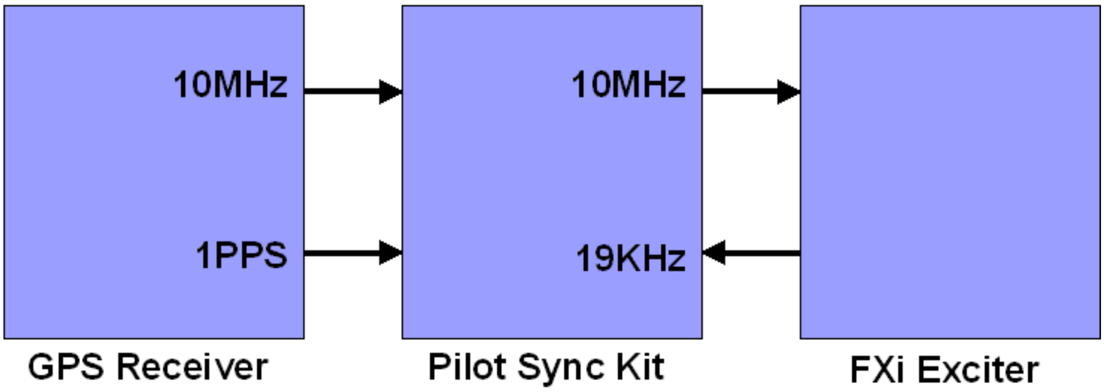

FIGURE 1—PILOT SYNC KIT

Utilizing its FXi exciter technology, Broadcast Electronics has configured, tested and successfully implemented a system that has set a new standard for digital synchronous FM performance. A system installed for Antenna FM in Athens, Greece in 2002 has proven this technology directly in comparison with other methods on the market, and has been operating successfully for over a year, and two more systems have been installed in Athens. Subsequent systems have been installed across the US, as well as in New Zealand and the Philippines.

System Design

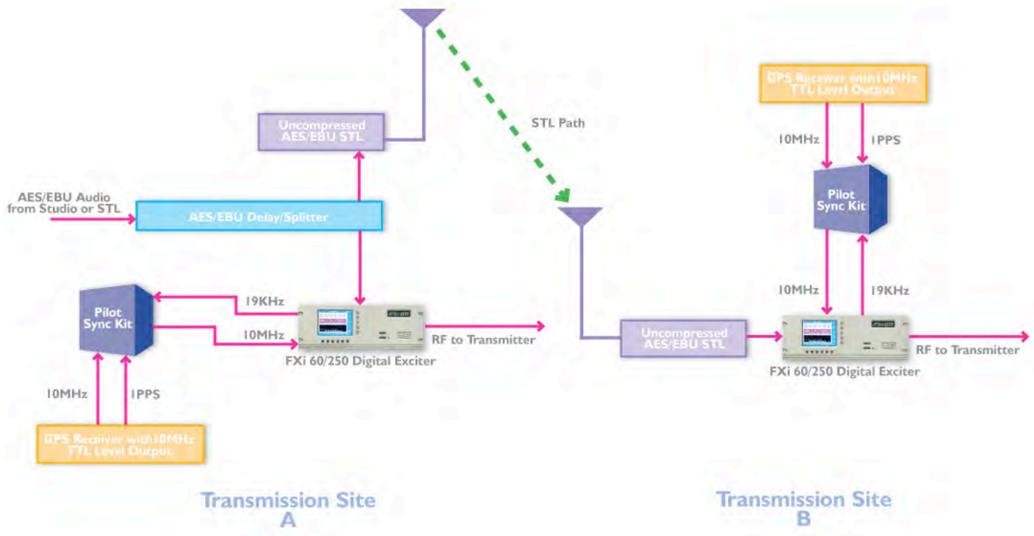

FIGURE 2—SYSTEM DIAGRAM

This design assumes that an uncompressed AES/EBU program audio link can be installed between transmission site A and transmission site B.

Steps to implement this mode:

1. Set both FXi exciters to lock to the external 10 MHz reference frequency.
2. Adjust the FXi exciter at transmission site A for proper modulation as fed from the studio audio processor. Note the exact AES input gain reading on the FXi LCD screen in the audio input menu.
3. Set the FXi exciter at transmission site B for the exact same AES input gain level as is set in the FXi exciter at transmission site A.

One of the most critical factors in the successful implementation of these system designs is to compensate for the difference in distance between the link paths from the studio to the two (or more) transmission sites. The differing lengths of the link paths cause the audio program to arrive at the farthest transmission site slightly after the signal destined for the nearer site. Even though the distance may differ by only a few kilometers or less, the difference may produce audible noise and distortion. To compensate, an AES/EBU delay unit is required, with extremely fine resolution, ideally producing an adjustable delay of as little as one microsecond.

The digital delay unit should be adjusted so that the signals arrive at the interference zone at precisely the same time. Please refer to Figure 3 below. After calculating, enter this figure into the delay unit in microseconds.

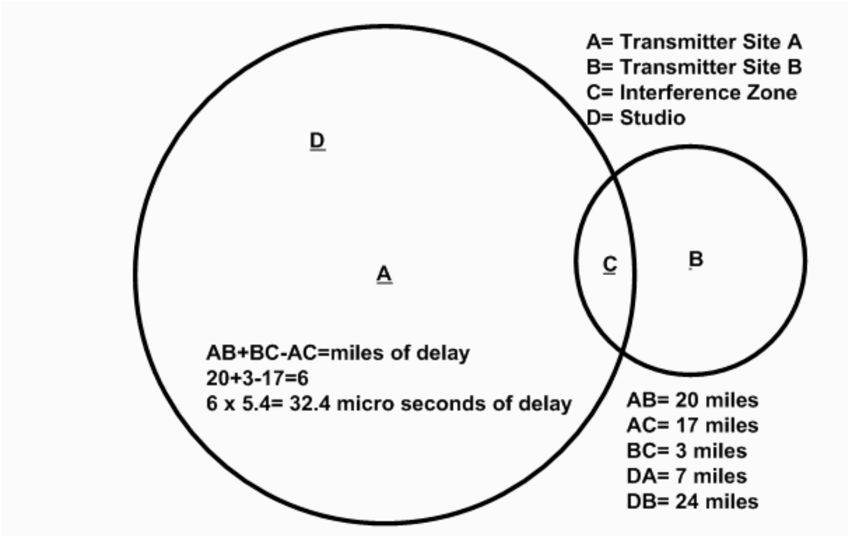

FIGURE 3 —CALCULATING DELAYS

To adjust the delay use 5.4 microseconds per mile or 3.4 microseconds per kilometer. Additional adjustment may then be made by driving through the overlap area with a mobile phone or radio and communicating with a technician at transmission site A to adjust the delay slightly in each direction for optimized signal quality. When properly adjusted, the audio performance in the interference zone should be similar to normal multi-path distortion.

This will also work with an analog STL between the studio and the first transmission site. To do this, an Analog-Digital converter will be required before the signal enters the AES/EBU Delay Unit.

It is also possible to design the system using uncompressed digital links between the studio and each transmission site, or to use an asynchronous link mode and an external synchronizer such as the Harris Intraplex.

Proving the Theory

To test this design, we modeled the transmission system, and Figure 4 shows the graphical results of the composite baseband – unadulterated.

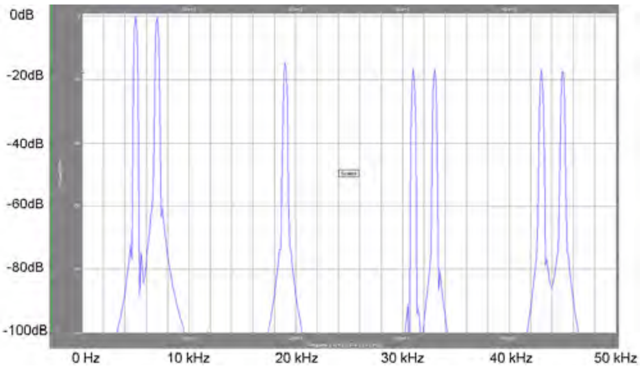

FIGURE 4—COMPOSITE BASEBAND

Figure 5 shows the effect of a ½ dB difference in modulation level, with equal amplitudes, of two otherwise synchronized signals. This is the effect of the white noise, which has been noted by many engineers in a system where the modulation is not precisely matched.

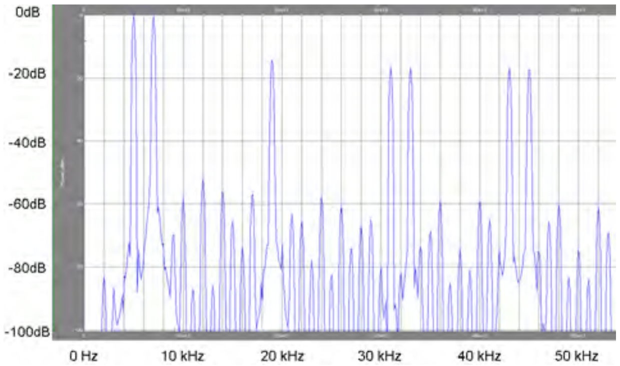

FIGURE 5—1/2 DB DEVIATION DIFFERENCE

By comparison, Figure 6 is a graph showing the effect of worst-case multipath, equal levels, 180-degree phase difference, but synchronized modulation.

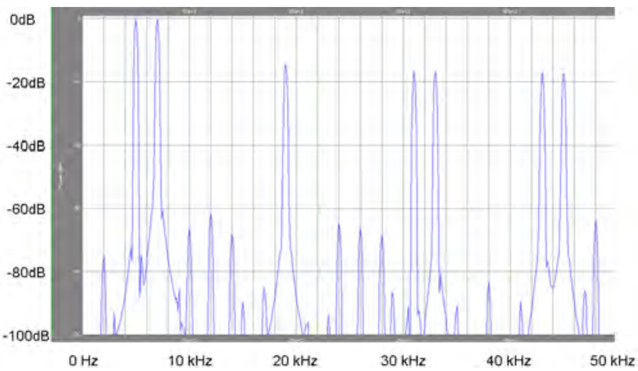

FIGURE 6—MULTIPATH

It can be seen that the effect of slight amounts of modulation level mismatch can produce serious broadband noise in the composite baseband.

System Engineering Considerations

In addition to the selection of the correct booster technology, the importance of a proper RF engineering study and system design cannot be underemphasized. Broadcasters who ignore the planning aspect of their booster project run the risk of creating more reception problems with two transmitters than they experienced with one. Here are some of the factors that need to be considered in such a study:

- It has been found that most FM broadcasters who complain of poor coverage due to shadowing caused by terrain or buildings actually have adequate signal strength in the interference area, and are in fact suffering from severe multipath conditions. A booster cannot overcome multipath problems unless the booster signal is significantly stronger than the main station signal throughout the multipath area.
- The booster transmitter location should be chosen with great care. Terrain shielding should be used whenever possible to limit the range and coverage of the booster to the problem area.
- Avoid the temptation to install a booster at a high altitude location. Lower altitude sites will tend to restrict the booster coverage to the immediate problem area, reduce the size of the interference zones, and will avoid the creation of new pockets of interference far removed from the problem area.
- Avoid the use of too much booster transmitter power. Low power boosters will do a better job of filling in localized problem areas while avoiding the creation of large interference zones.
- Careful choice of directional antennas for FM boosters will allow better control of the size and location of the interference zones. While it's impossible to eliminate these zones, proper tailoring of the booster coverage can locate them in minimum population areas. Yagi or log periodic antennas are preferred over omni-directional antennas. They should be oriented so that their main lobes are directed towards the areas of problem reception, while their nulls are used to minimize booster signal transmission towards areas of clear reception.
- Coverage prediction software using terrain analysis can be immensely valuable in studying a variety of possible transmission sites and antenna combinations. Signal strength levels can be accurately predicted for both the main and booster stations, allowing for the prediction of the location and size of the interference zones with changes in booster location, transmitter power and antenna patterns.

Limitations to this Approach

It's important to realize that the BE Sync FM approach is not a system, but is instead a collection of products that can be used to create reliable and high performance system. RF design, typically done by an RF consultant to minimize the size and ideally locate the interference zones is still critical, and Broadcast Electronics does not provide RF consulting services.

Conclusions

FM boosters utilizing the latest technologies, when properly designed and implemented, can prove to be a solution to many FM station coverage problems, and can significantly improve the commercial viability of a marginal station property. True, regional stations, preserving station identity, may be created by synchronizing high power stations The frequency is the same across the entire region, making frequency allocation easier for spectrum regulators.

References

Anthony, Edward, *Implementation Of A Reliable Synchronous FM Booster.* http://www.bdcast.com/manuals/PAPER/FM/SYNCHBOS.pdf

Acknowledgements

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